

## SLAGGING BEHAVIOUR OF PEAT ASH

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### INTRODUCTION

The use of peat for energy production in Finland dates back to early 1970's. For the present, the peat combustion is responsible for over 5 % of the energy production in Finland. Many of the major Finnish power plants still use pulverised fuel, but the utilisation of fluidised bed boilers is rapidly increasing. Boilers of this type are best suited for fuel with a low energy value because the increased efficiency is beneficial for the community heat distribution.

The Toppila power plant of Oulu Energy Company in the city of Oulu, Finland has two units. The older one, Toppila I, is a 250 MW boiler using pulverised peat as fuel. The new Toppila II boiler is a 310 MW circulating fluidised bed boiler. The power plant uses 15 000 m<sup>3</sup> of peat per day with full load.

The slagging behaviour of peat ash varies depending on the bog peat it is originating. The plant shutdown because of extensive slagging may cause significant economical losses in the entire chain of energy production. Therefore the slagging behaviour of peat ash needs to be predicted already from peat prior to its combustion.

In coal ash chemistry the slag formation is connected to the presence of iron, sulphur, alkaline and earth alkaline metals in ash. These metals act as fluxing agents in aluminium silicate systems.<sup>1-3</sup> Several predictive indices have been developed for coal in order to estimate the slagging tendency of coal ash.<sup>4</sup> These indices are based on the bulk analysis carried out in laboratory conditions using standard ashing methods.<sup>5</sup> These indices have been criticized, because the ash is not formed in the actual turbulent conditions with fast heating rate and real gas phase composition.<sup>6</sup> New methods have been developed to understand the sintering and slagging events. These methods use coal analyses, power plant parameters, ash analyses together with CCSEM, analyses from probe samples, fly ash samples, bottom ash samples, aerosols etc.<sup>4,7-10</sup>

### RESULTS AND DISCUSSION

In this study we report the slagging behaviour of five peat samples (A-E) of different origin. With the exception of B the samples were collected from Toppila I and originate from Northern Finland. Samples of standard ash were analysed by using ICP- and DCP-AES, X-ray diffraction (XRD), and scanning electron microscopy with energy dispersive X-ray microanalysis (SEM-EDS). Table 1 presents the both the CHNS-analysis of the original peat sample and the elemental bulk compositions of standard ash from each sample.

The ash of peat A that is known to have a strong tendency to slag contains remarkable quantities of iron and relatively small amounts of aluminium and silicon oxides. The content of alkaline metals is quite low. The ash of peat B also known to be problematic contains a remarkably high amount of calcium. The sulphur content is also higher than in the harmless peat types C, D, and E.

X-ray diffraction powder diagrams were recorded with a Siemens D5000 diffractometer. Ash samples were carefully ground and mixed with ethyl alcohol to make a slurry which was spread on a glass plate for the diffraction experiment. Quartz, albite and anorthite are the most common minerals in peat ash. The tendency of peat ash to slag seems to correlate with high amounts of haematite and maghemite (peat A) or anhydrite (peat B).

Scanning electron microscopy (Jeol JSM-6400 and Link eXL system with the image analysis software) provides simultaneous information on the chemical composition and mineral content of fuel ash particles.

The mineral content of original peat is very low and the particles seem to be scattered throughout the organic material. Therefore we could not observe any minerals in peat. It was only after standard ashing<sup>5</sup> that inorganic material was visible in the SEM image.

The SEM images were produced by applying constant accelerating voltage of 15 kV and the current of 1.70·10<sup>-6</sup>A. The magnification was 430X. When possible, the minimum of one thousand particles were analysed.

The composition of peat ash based on CCSEM can be visualized by using appropriate distribution diagrams (see Figure 1). The classification yields useful information when the corners in these "ternary" digrams are defined in terms of the total content of selected oxides. The composition at each corner is chosen in order to gain information about the potential glass formation in the slag particles. It can easily be seen from the diagrams in Figure 1 that the phase distribution in the ash particles of the harmless peat E is different from that in the severely slagging peat A. It is obvious that the content of iron-rich particles is greatly enhanced in the problematic peat ash. While the bulk analyses shown in Figure 2 do not provide information about the composition of discrete particles, they do reflect the differences in the particle distribution between the slagging and harmless fuel in a qualitative fashion (c.f. Figure 1).

The slagging indices were calculated from the bulk analysis of peat ash. As these indices have been developed for coal and depend on the sulfur content found in coal,<sup>4</sup> they are not suitable for the prediction of slagging behaviour of peat ash due to the very low sulphur content in each peat sample. This is exemplified in Figure 3 that shows the slagging index,  $R_s$ , of the standard ash for each peat sample A-E. In each case the slagging index implies relatively unproblematic behaviour upon combustion. It is known, however, that the peat A and B show a severe tendency to slag, whereas the peat C, D, and E are known to be relatively harmless. As seen from Figure 3, the slagging index does not carry information even on the relative slagging tendency. This is due not only to the low sulphur content but also due to the differences in the contents of silicon, phosphorous, sodium, potassium, calcium, and iron.

Two extensive tests in an actual power plant boiler have also been carried out. Samples were collected from the fireside by use of the slagging probes. Analyses were made from samples taken from fuel, slagging probes, and fly ash. The evaluation of the results is currently in progress, but it already seems apparent that the standard ash does not behave similarly to the actual boiler ash in all respects.

#### CONCLUSIONS

It is one of the corner stones in coal and glass chemistry<sup>1,11</sup> that alkaline metals, alkaline earth metals, iron, sulphur and phosphorous are able to lower the melting point and increase the viscosities of fuel ash particles. This phenomenon may lead to a severe slagging problem in the boiler superheater and wall area. It is important to design predictive tools for the ash slagging in order to prevent the major economical losses caused by a possible plant shutdown.

The mineral material in peat differs to a certain extent from that in coal. For example, both coal and peat contain iron in significant amounts. Coal, however, contains sulfur in larger amounts than peat, because iron is found as pyrite in coal, whereas in peat it occurs as siderite or as haematite. Therefore, we are currently developing a new classification technique to establish the mineral distribution of peat and peat ash particles. The method is based on CCSEM. The conventional classification utilizing CCSEM is based on the identification of mineral phases from the elemental composition of the particles. This approach might not be useful in the case of ash particles, since extensive glass formation takes place upon combustion. Therefore, the particle distribution is best judged on the basis of oxide distribution as illustrated in Figure 1. The choice of suitable corned compositions enables meaningful deductions to be made about the actual phases in the ash particles. The mineral composition of bulk ash can be studied with XRD powder diffraction. The tendency of ash vitrification, however, can also be observed from the shape of the diffraction diagrams.

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Table 1. Ultimate and ash analyses of peat (A,C-E peat from domestic sources; B peat from abroad). A and B exhibit severe slagging. C-E are harmless.

Ultimate analysis	A %	B %	C %	D %	E %
C	49,1	50,3	52,9	51,0	52,0
H	6,08	5,84	6,34	6,66	6,39
N	2,77	1,44	2,50	2,79	1,27
S	0,22	0,31	0,27	0,21	0,13
O	32,9	35,6	33,8	33,5	36,6
ash	8,96	6,51	4,18	5,81	3,58
Standard ash composition of peat					
Na	0,02	1,10	0,43	0,43	1,48
Mg	0,78	2,92	2,32	1,15	1,68
Al	3,20	4,64	4,41	4,23	6,79
Si	6,17	17,31	8,87	17,40	19,64
P	4,62	1,34	2,28	2,35	1,97
K	0,06	0,96	0,83	2,47	2,75
Ca	7,99	21,53	17,14	8,00	9,17
Ti	0,06	0,31	0,15	0,14	0,50
Fe	61,37	7,68	38,97	27,79	18,56
B	0,19	0,04	0,23	0,15	0,21

\* calculated value

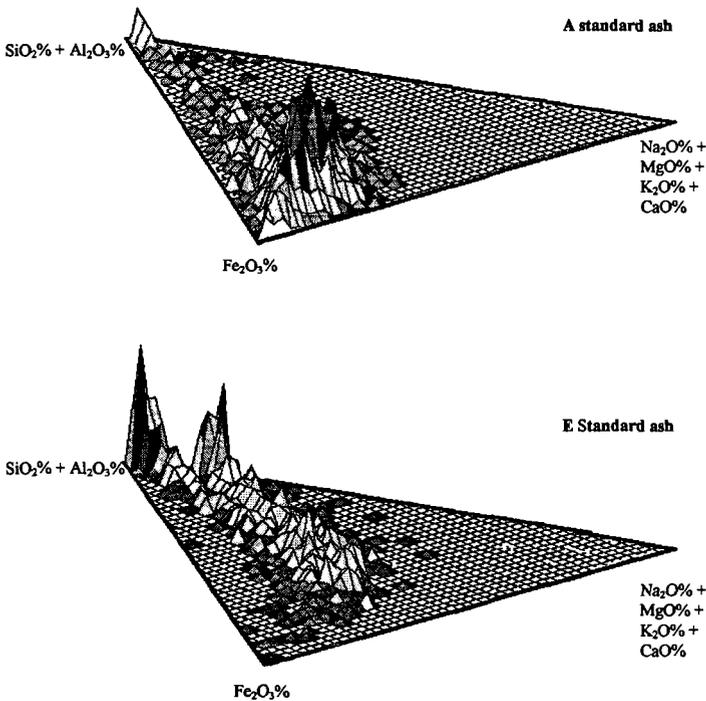


Figure 1. The compositional distribution of ash particles in slagging (A) and harmless (E) peat. The height of the column relates to the fraction of particles with the indicated composition. The ash particles of peat A are concentrated in the iron-rich region in the diagram implying the presence of low melting iron-silicates.

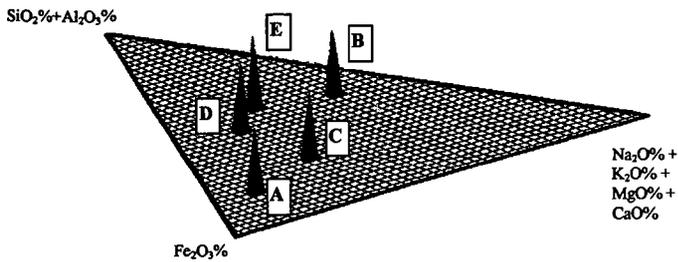


Figure 2. The bulk composition of standard ash from peat A-E.

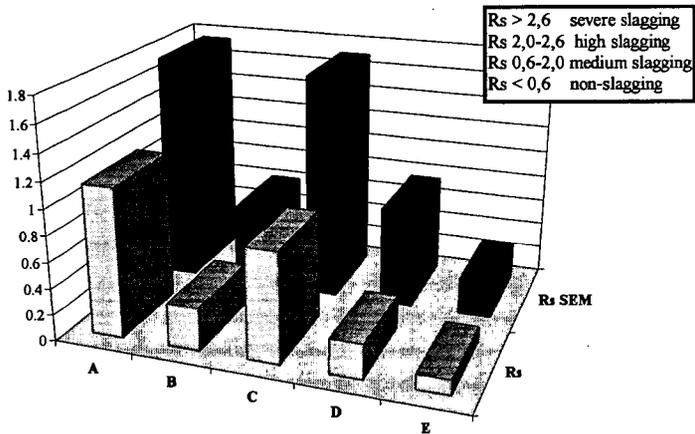


Figure 3. The slugging index <sup>4</sup> was calculated both from the bulk ash composition ( $R_s$ ) and from the particle compositions as determined with SEM-EDS ( $R_s \text{ SEM}$ ). Both indices show the same trends. As indicated in the figure, these values are typical for non-slugging or medium slugging ash. However, due to the very low sulfur content in peat,  $R_s$  index is not directly applicable to peat. In fact A and B have turned out to exhibit severe slugging behaviour.